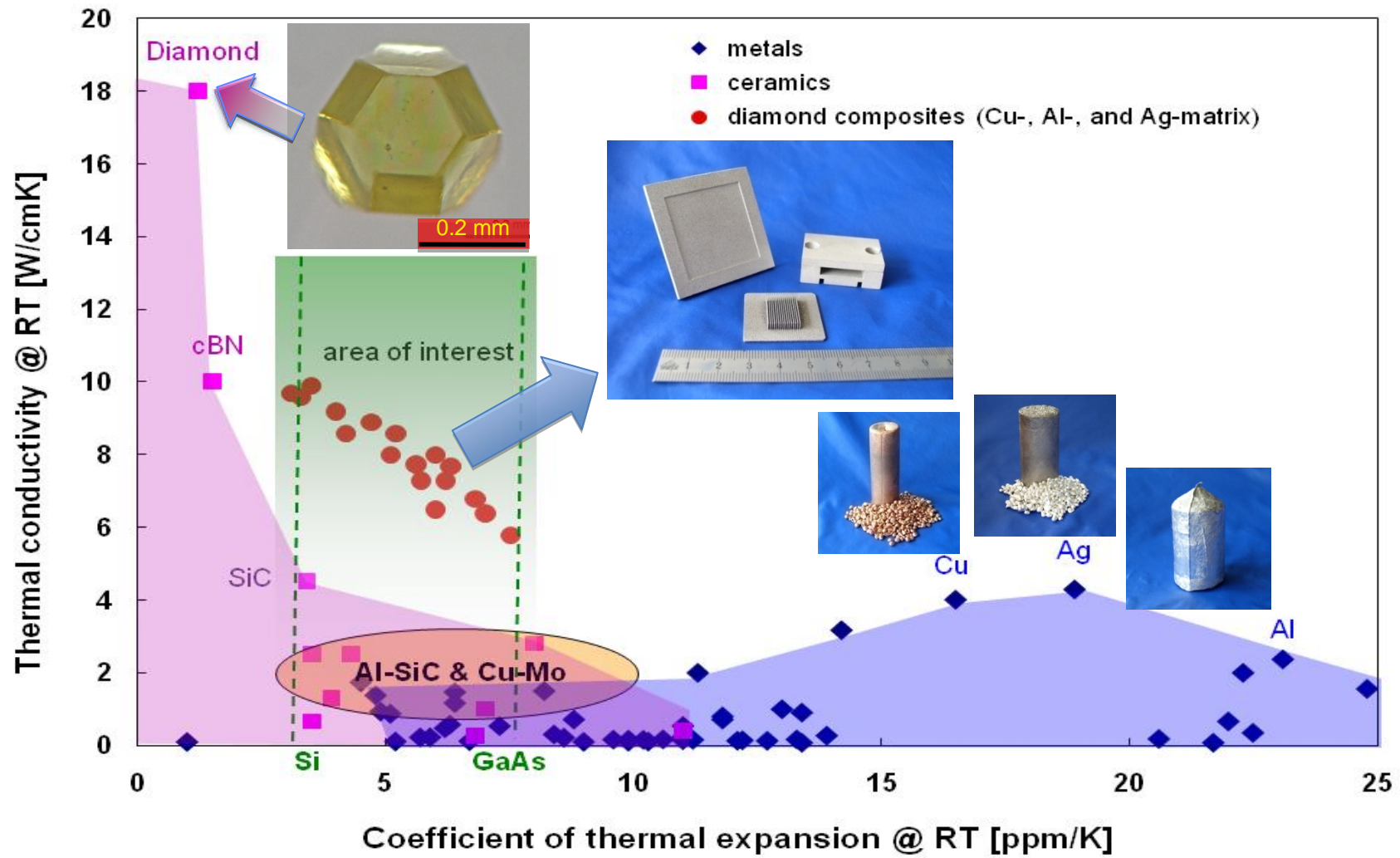


Diamond-based Metal Matrix Composites: The influence of thermal cycling on their thermophysical properties

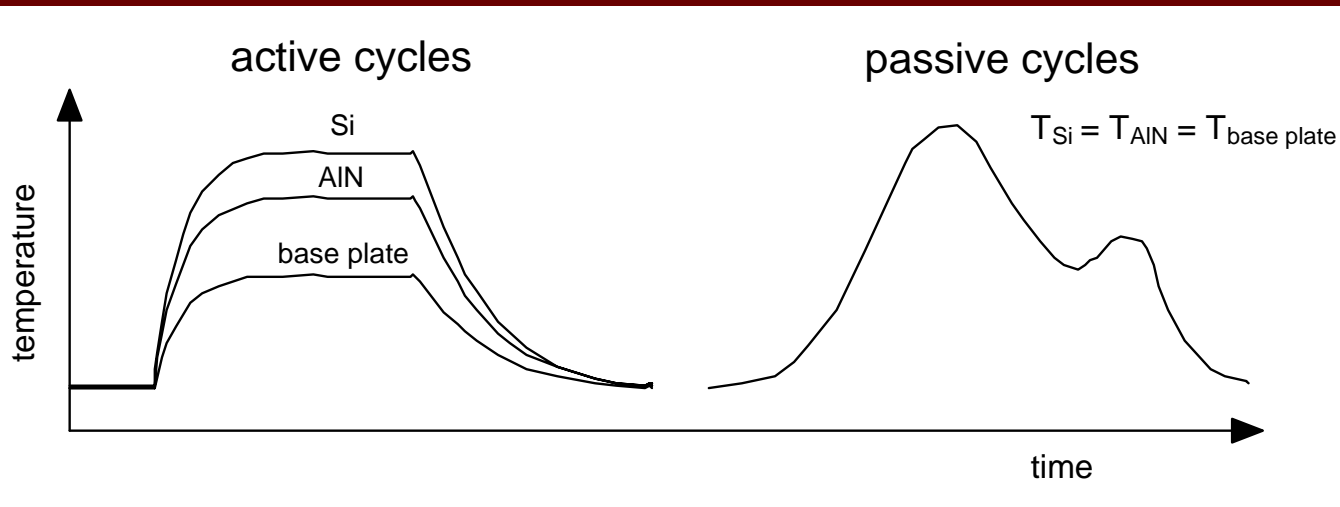
R. Tavangar, L. Weber

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CH-1015, Lausanne, Switzerland

Candidate Materials



The heat is on!...and off!...and on!...and...



Active cycles:

- on/off

Passive cycles:

- day/night
- summer/winter
- brazing
- etc...

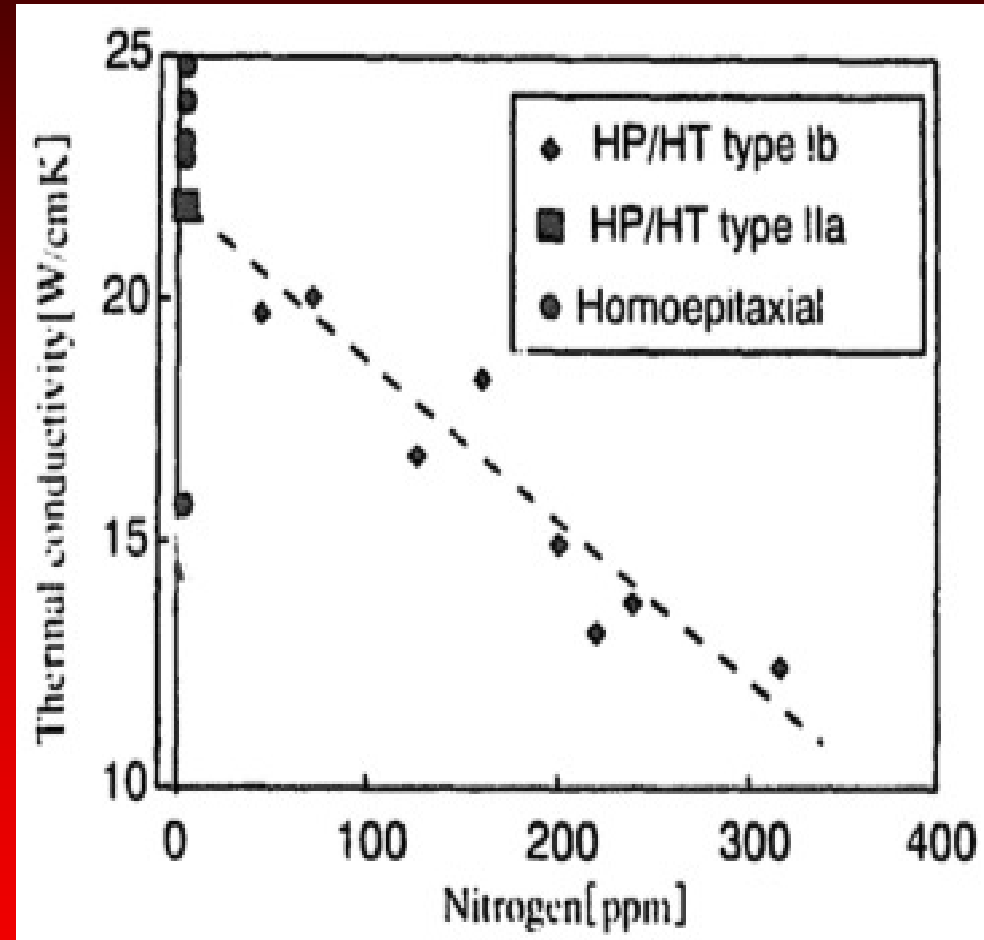
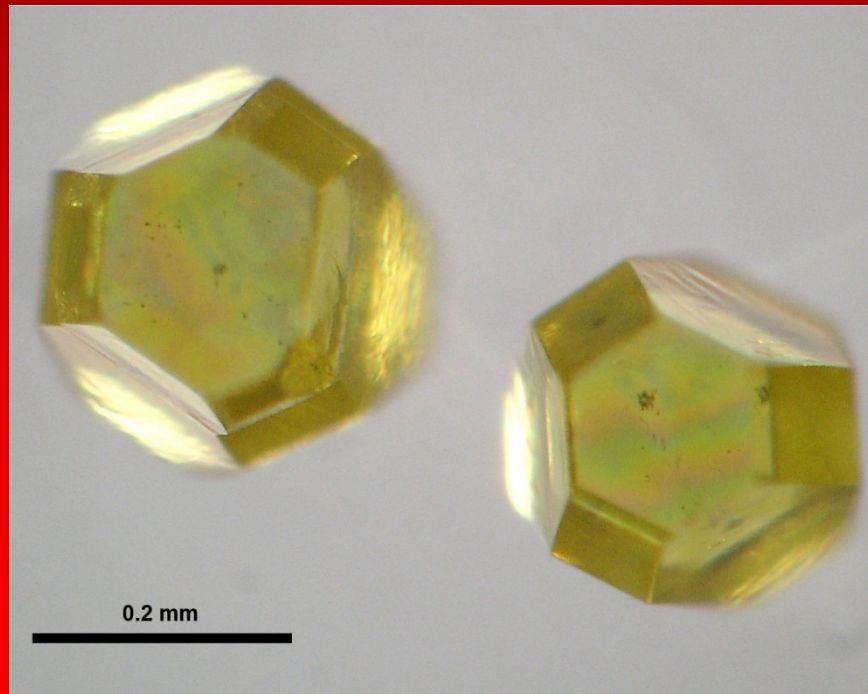
Thermal cycles cause thermo-mechanical fatigue in the (often soldered) interface!

=> The CTE of the materials involved needs to be compatible!

The making of diamond composites

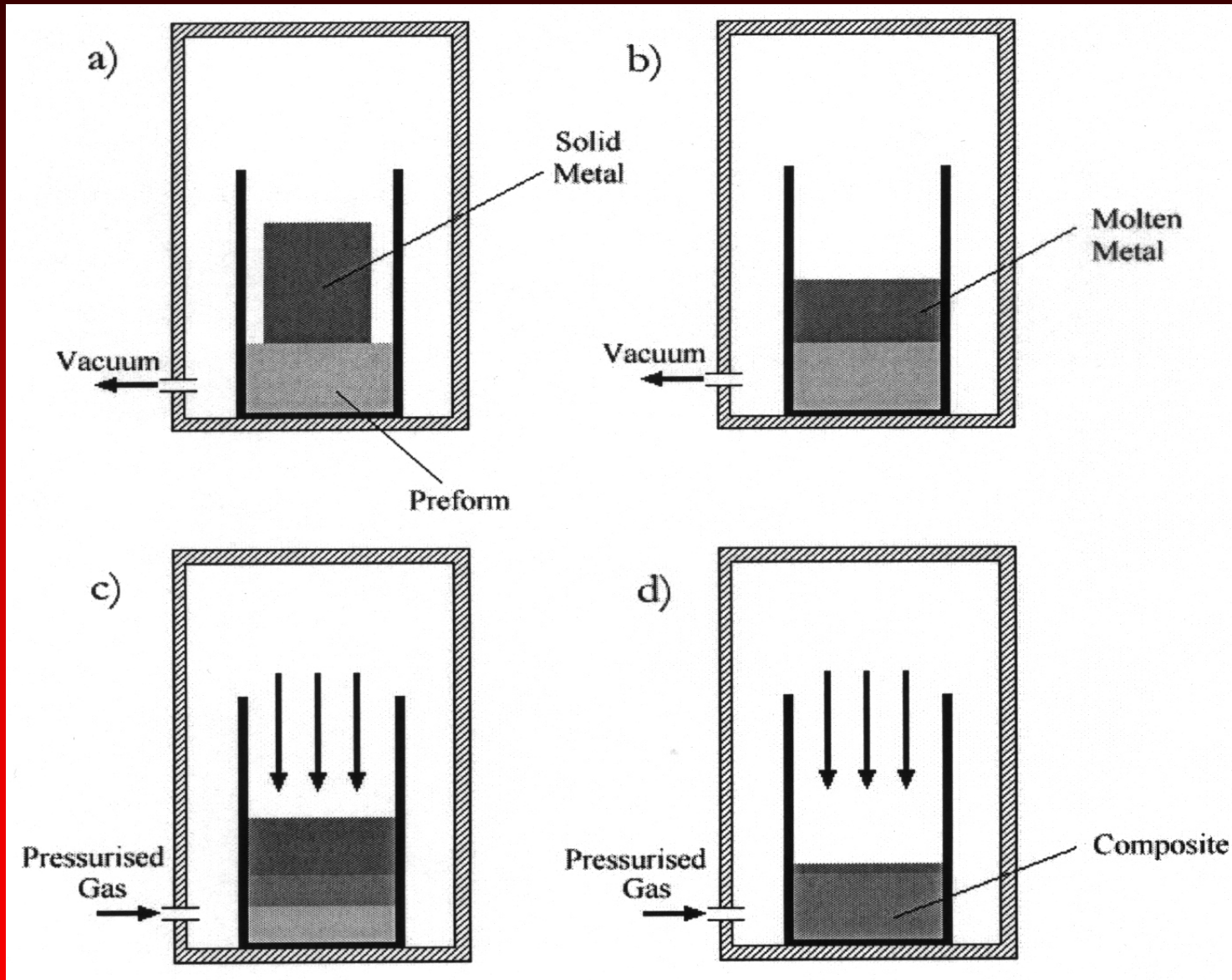
Selected diamond grit

- Mono-crystalline diamond
- Low nitrogen level
- Relatively large size ($>100\mu\text{m}$)

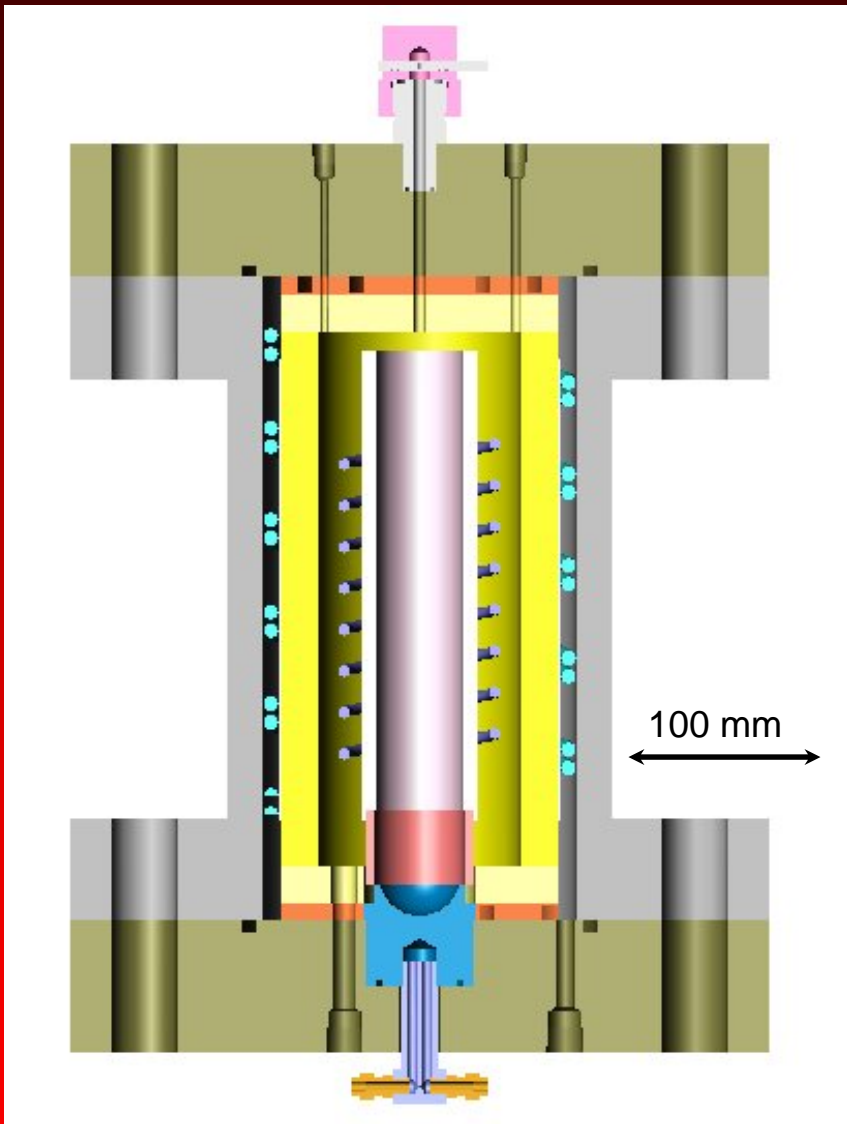


Yamamoto, Y. et al.: *Diamond*
Rel. Mat. 6 (1997) 1057

Liquid metal infiltration process



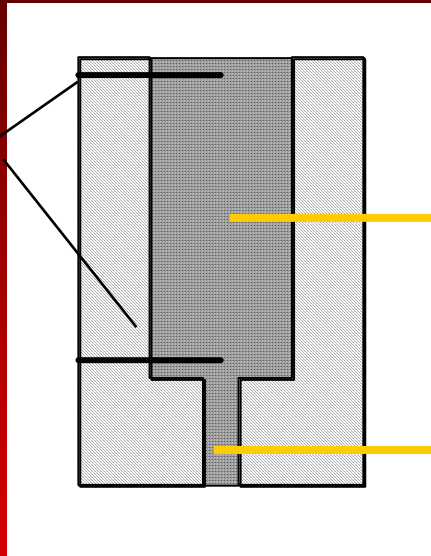
Pressure infiltration apparatus



- **Cold wall vessel** (250 bar, 200°C)
Inner side of the wall in contact with a water cooled heat shield
- **Induction heating**
(using a graphite susceptor)
- **primary vacuum pump**
(0.1 mbar)
- **Crucible can be lowered on quench** (directional solidification)

Net-shape sample fabrication

Graphite
space
holders



TC sample

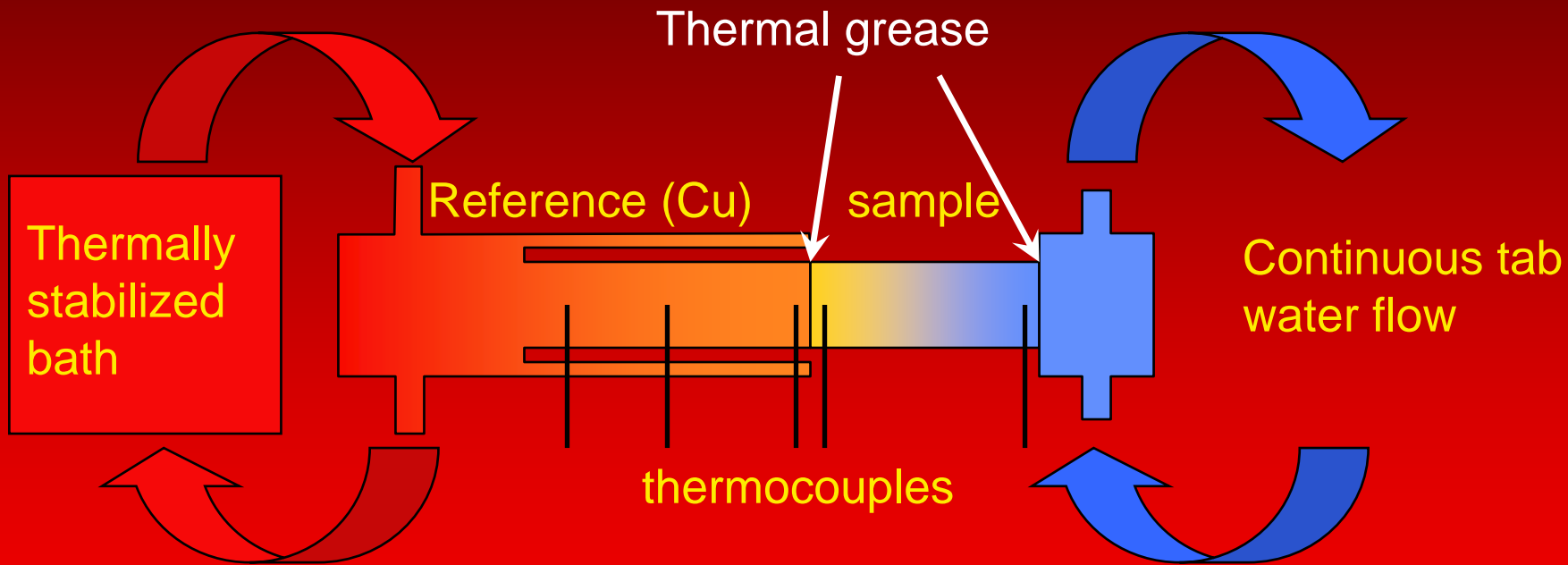
CTE sample



Thermal conductivity and expansion measurement

Thermal conductivity measurement

Stationary Method:



$$A_{ref} j_{ref} = -\lambda_{ref} \nabla T_{ref} A_{ref} = A_{sample} j_{sample} = -\lambda_{sample} \nabla T_{sample} A_{sample}$$

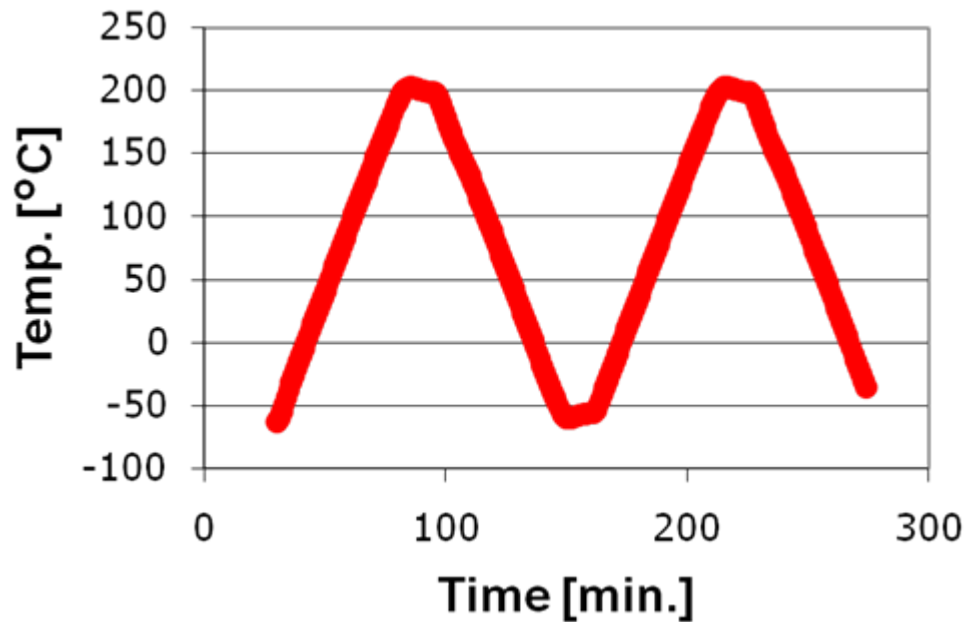
Push-rod (Netzsch)

- Specifications:

Min Temp.= -150°C[LN]

-120°C[GN]

Max Temp.= 500°C/1000°C

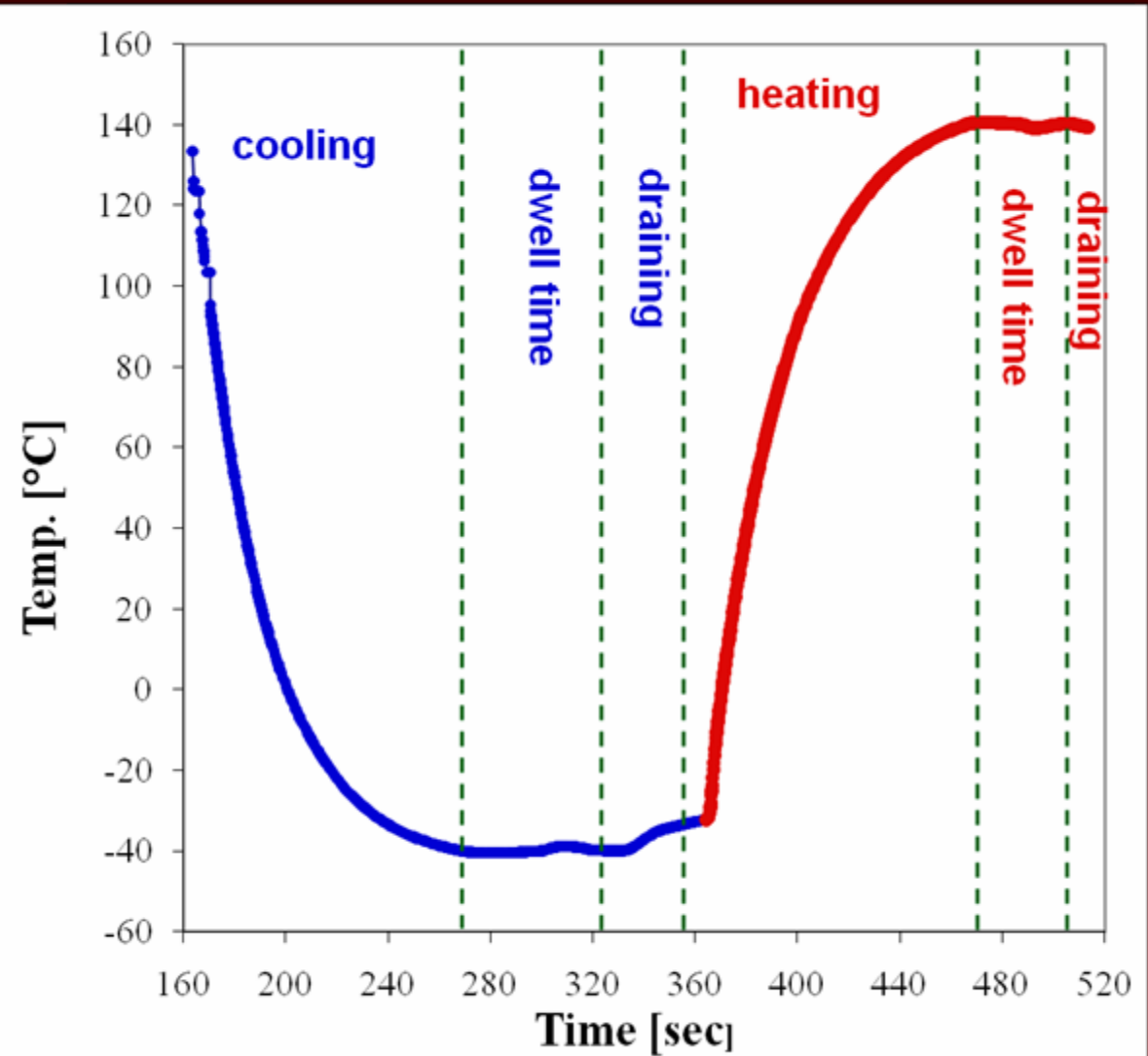


Thermal cycling

Thermal cycling

Specifications:

- Change Liquid type
- T Min/Max: -40/140 °C
- Cycle Time: 6 min



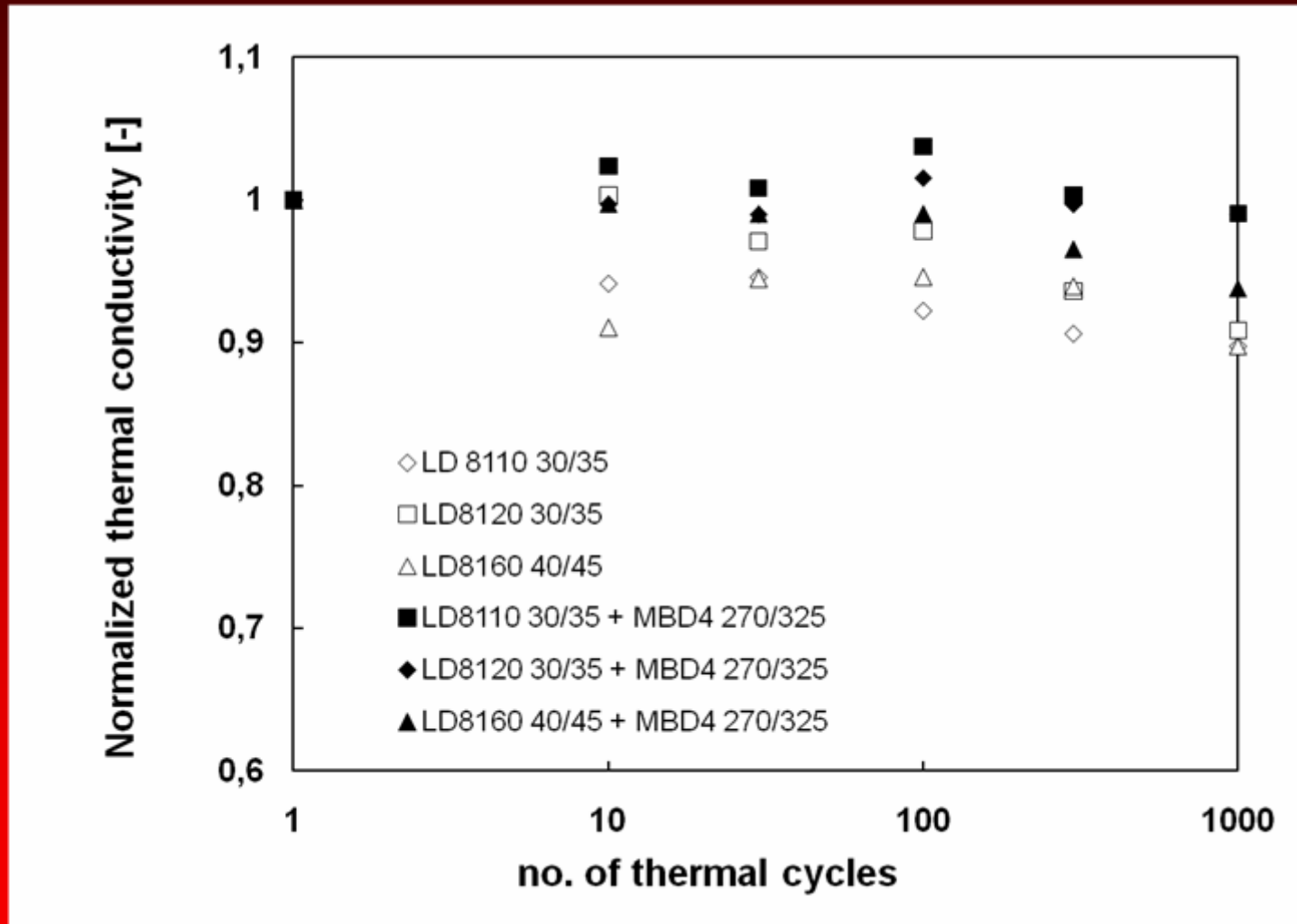
Thermal conductivity of Al diamond composites

Composite	Volume Fraction	Thermal Conductivity W/mK
LD 8110 30/35	0.61	685
LD 8120 30/35	0.62	690
LD 8160 40/45	0.65	760
LD 8110 30/35+MBD4 270/325	0.73	720
LD 8120 30/35+MBD4 270/325	0.74	702
LD 8160 40/45+MBD4 270/325	0.76	725

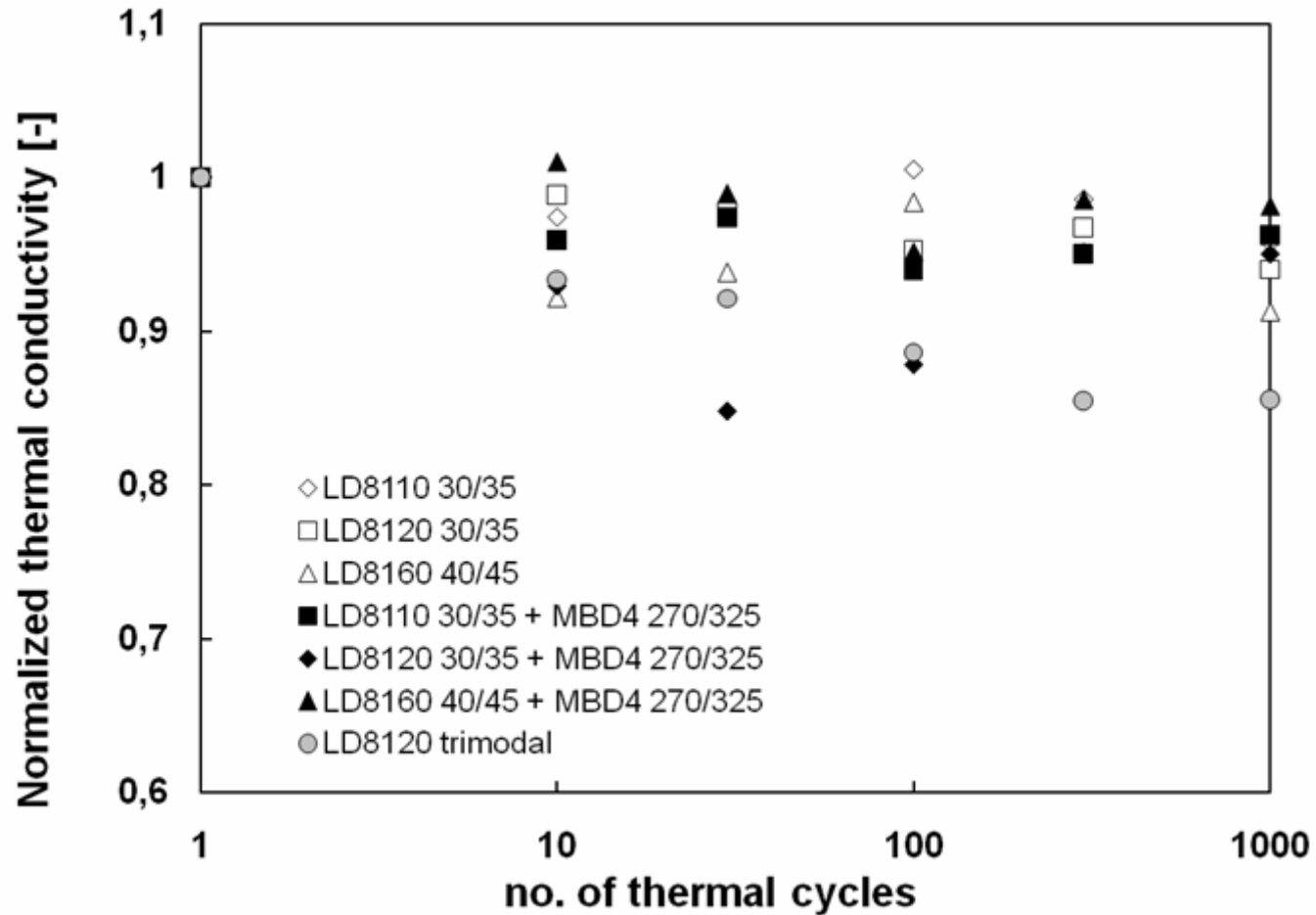
Thermal conductivity of Ag-based diamond composites

Composite	Volume Fraction	Thermal Conductivity As Infiltrated W/mK	Thermal Conductivity Heat treated W/mK
LD 8110 30/35	0.61	725	775
LD 8120 30/35	0.62	760	800
LD 8160 40/45	0.65	795	860
LD 8110 30/35+MBD4 270/325	0.73	900	960
LD 8120 30/35+MBD4 270/325	0.74	910	960
LD 8160 40/45+MBD4 270/325	0.76	960	970
LD 8120 30/35 Trimodal	0.77	778	825

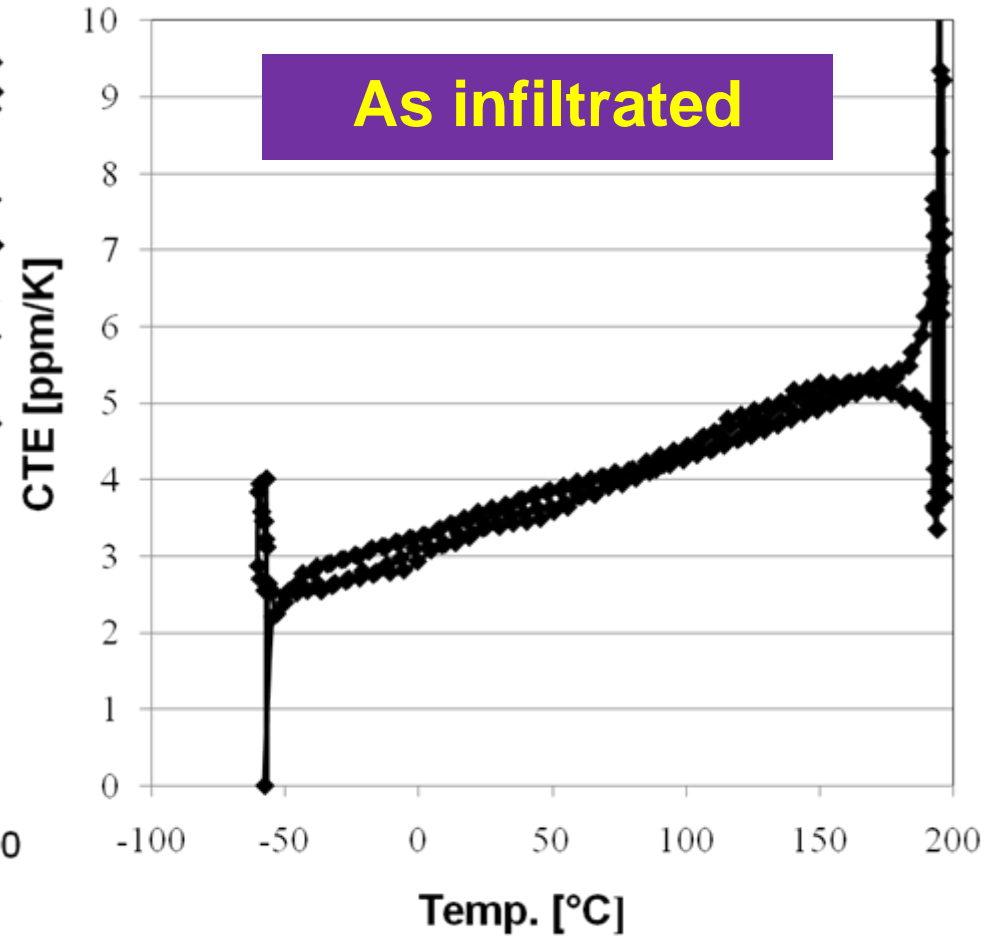
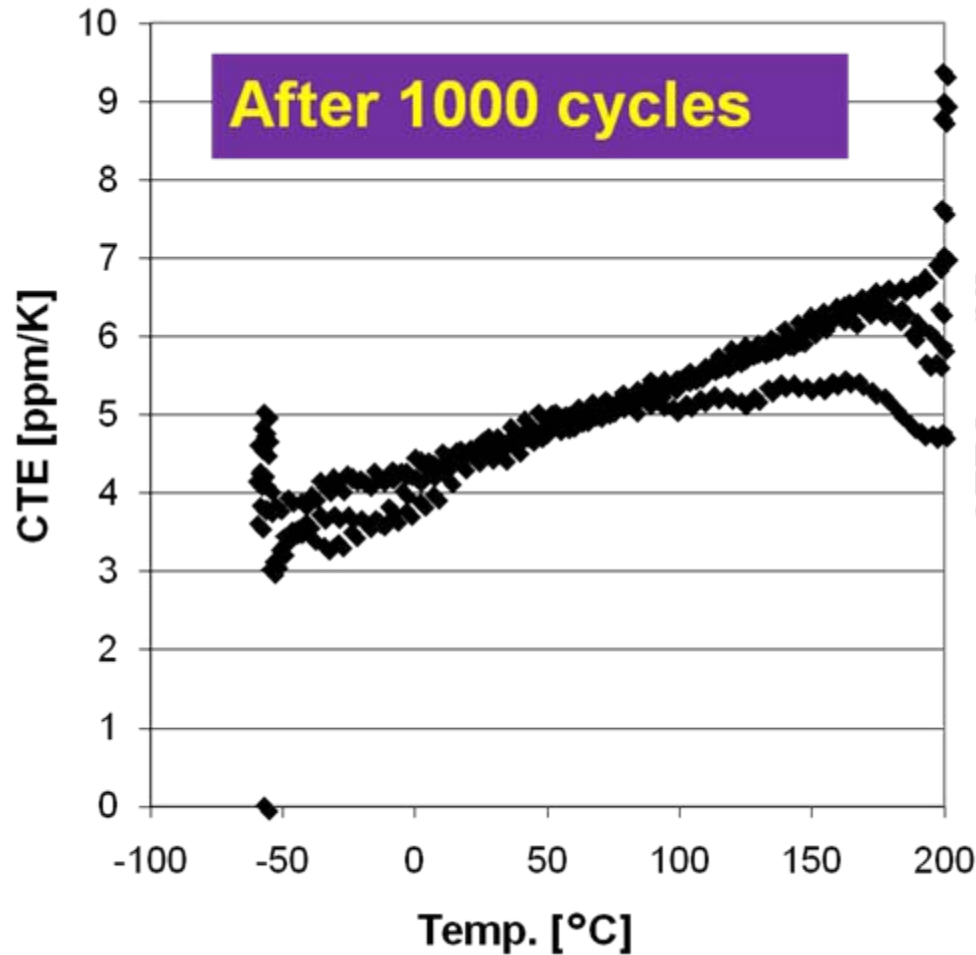
Thermal conductivity of Al diamond after thermal cycling



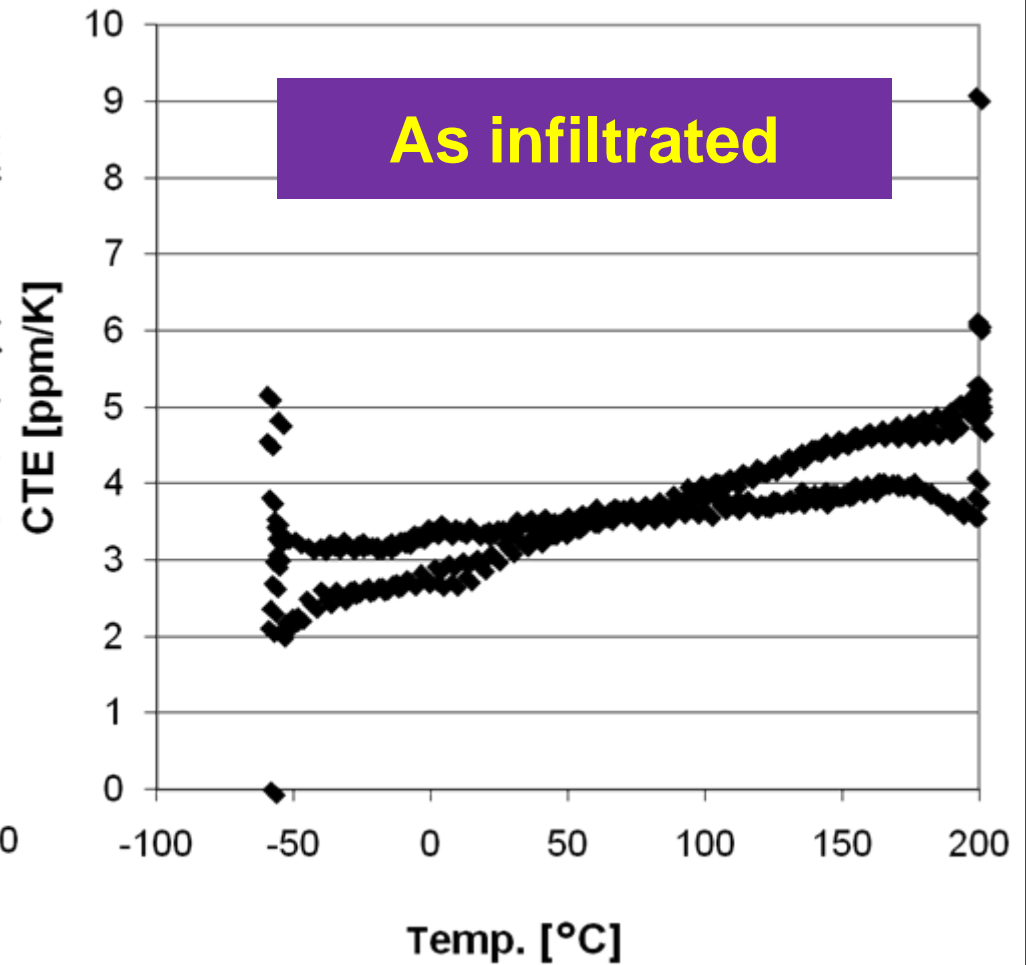
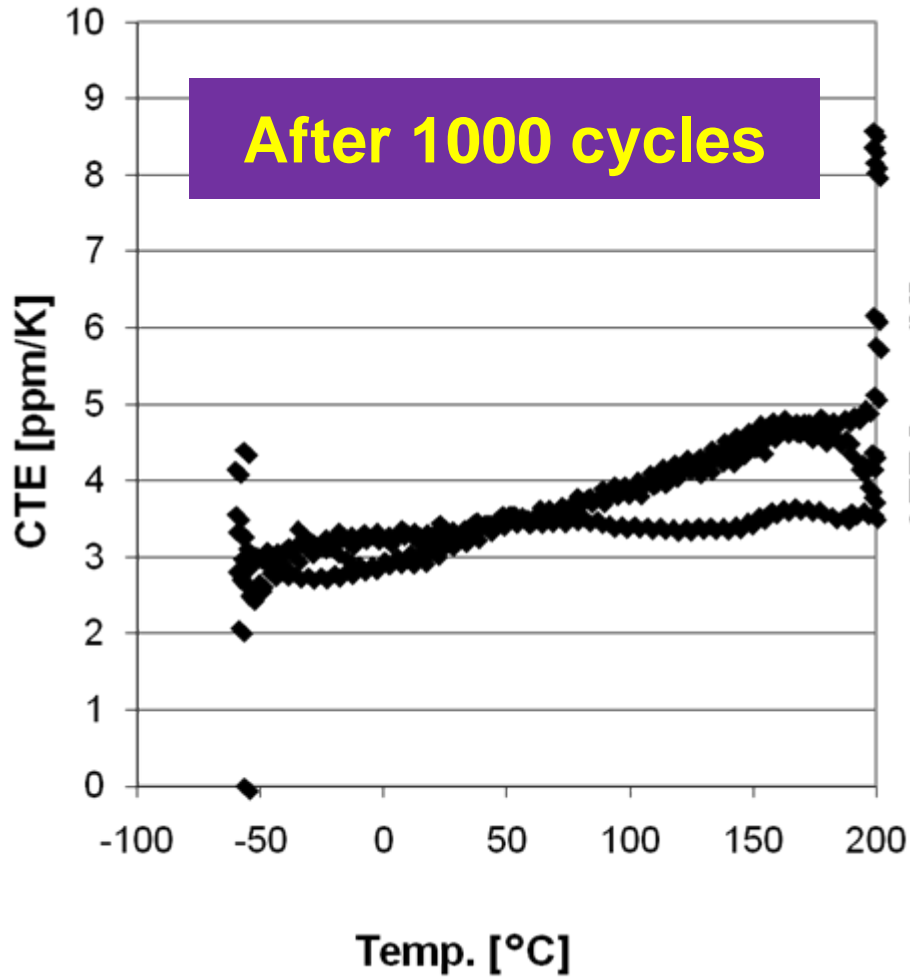
Thermal conductivity of Ag-based diamond after thermal cycling



Thermal Expansion of Al/bimodal diamond composite



Thermal Expansion of Ag-based/bimodal diamond composite



Thermal Expansion of Al diamond at Room Temperature

Designation	CTE at Room Temp.[ppm/K]	CTE at Room Temp.[ppm/K] after 1000 cycles
pure Al/diamond		
LD 8120 30/35	6.95	8.40
LD 8110 30/35	6.60	7.70
LD 8160 40/45	5.70	7.50
LD 8110 30/35+MBD4 270/325	3.40	4.20
LD 8120 30/35+MBD4 270/325	3.68	4.60
LD 8160 40/45+MBD4 270/325	3.43	4.70

Thermal Expansion of Ag-based diamond at Room Temperature

Designation	CTE [ppm/K]	CTE [ppm/K] After 1000 cycles
Ag-based/diamond		
LD 8120 30/35	5.05	5.80
LD 8110 30/35	5.60	6.00
LD 8160 40/45	5.20	5.80
LD 8110 30/35+MBD4 270/325	3.34	3.45
LD 8120 30/35+MBD4 270/325	3.33	3.45
LD 8160 40/45+MBD4 270/325	3.05	3.10
LD 8120 30/35+MBD4 270/325+CK-J (6-30 μm)	2.98	3.15

Summary

- Both Al and Ag-based diamond composites are quite stable against thermal cycling. Composites using bimodal powders seem to offer better stability.
- Al/diamond with bimodal powder mixtures showed lower thermal expansion at the expense of thermal conductivity and thus a trade off must be made for these two properties.
- Specifications regarding the CTE of a diamond composite need to include the temperature range.

Acknowledgement

Financial support from EU FP6 integrated project “ExtreMat” under the contract NMP-CT-2004-500253 and stimulating discussions with all partners we have been collaborating with, are gratefully acknowledged.

Thanks for your attention

Hmm! Was this you promised to the audience to be the best for **last!!**



I'm so sorry that I could not reach **1000 W/mK!**

After 1000 cycles

